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Abstract: The paper investigates energy market integration in China by employing univariate, and panel-based unit root tests and Granger causality tests applied to a new, energy price data set. We identify price series that converge either to absolute or relative price parity. In addition we estimate the rates (speed) at which relative prices converge to their long-run values, and the direction of causality. The results show that gasoline and diesel markets are very well integrated as a whole; that once some geographically isolated regions are excluded, we can regard the coal market as integrated; however, the electricity markets is not well integrated. The estimated intercept terms are all very small and close to zero, such that most of the relative price series can be regarded as convergent to absolute price parity. The convergence rates vary little and are relatively short when compared internationally. A rich set of causal relationships are established many showing bi-directional causality between regional centres.

Key words: China; Energy; Market integration; Price convergence; Time series tests

JEL classifications: D24, O33, Q41

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1. Introduction

The ongoing transition of former communist countries from planned to market economies has been one of the most important economic phenomena in the last few decades. It is interesting, therefore, to consider whether the liberalization of domestic trade prompts major shifts in price structures that were highly distorted under central planning (Fan and Wei, 2006). Such a study is interesting because of the ongoing debate as to whether China's gradualist reform has been successful (see Lau, Qian and Roland, 2000; Young, 2000; Poncet, 2003 and 2005). Since China embarked on its economic reform and adopted an open door policy in the late 1970s, its economic development has been greatly enhanced by its active participation in international trade. However, recently there has been more debate about domestic trade and China's major trading partners have strongly urged it to further open its domestic market, especially after it has admitted to the World Trade Organization (WTO). However, even if the Chinese government removes the barriers to international trade, the effectiveness of this policy might be compromised by regional trade barriers within China itself (Fan and Wei, 2006). It is thus useful to test whether domestic markets are in fact integrated which can then provide some important information on how the market works in China (Zhou, Wan and Chen, 2000). Such information may help the government decide on the extent to which it should intervene in the market (Wyeth, 1992) and how.

Oil prices have been extensively analysed in the literature over the past three decades (Lanza, Manera and Giovannini, 2005). Much of the applied research and policy studies have examined the role played by the price of oil in determining economic growth or inflation rates both in developed and developing countries (Adrangi et al., 2001; Asche et al., 2003; Stern, 2000; Girma and Paulson, 1999; Gjolberg and Johnsen, 1999; Serletis, 1994; Shaked and Sutton, 1982). Energy market integration has also been extensively investigated see for example, Asche, Osmundsen and Tveteras, (2002); Asche, Osmunddsen and Sandssmark, (2006); Bachmeier and Griffin, (2006); De Vany and Walls, (1999); Narayan and Smyth, (2005); Adrangi et al., (2001); Asche, Gjolberg and Volker, (2003); Gjolberg and Johnsen, (1999); Serletis, (1994) and Weiner, (1991). Recent work, however, reveals only one study, Fan and Wei (2006), which reports results for China and tests for *The Law of One Price* using 72 time series (41 industrial products, 20 agricultural products, 13 other consumer goods and 18 service products). However, their study includes only two fuel variables (gasoline and diesel), which one might expect, *a priori* to be the most likely to show market integration among the key energy inputs. To the best of our knowledge, there has been no specific study on energy market integration using data from China, which also considers two other key fuels, coal and electricity. Therefore, this study makes two contributions. Firstly, we investigate energy price movements using a new, high frequency, data set that consists of the market prices of four energy types (coal, electricity, gasoline and diesel) from 31 cities (all of which are provincial or autonomous regions and municipal cities) collected at 10-day intervals over a maximum of 132 months (from 1995 to 2005). Secondly, we provide results for two key energy input prices, coal and electricity, whose price convergence has not yet been reported for China.

The paper has four major goals. The first is to investigate energy market integration across major cities in China; the second is to test whether energy prices converge to absolute or relative price parity; the third is to estimate the rate at which relative prices converge to their long-run values across cities, and the fourth is to identify causal relationships across cities to observe how price information flows between cities. The rest of paper is organized as follows. Section 2 presents the empirical methodologies used, followed in Section 3 by a description of the new dataset utilised in the study. Section 4 presents the results and provides main findings. Section 5 concludes.

2. Methodologies

A common approach used to investigate market integration is to apply unit root tests to examine whether price differentials are stationary (see for example, Bernard and Durlauf 1996 and Greasley and Oxley, 1997). Rejection of the unit root hypothesis implies that the time series of relative prices are stationary, such that relative prices will converge in the long run. Otherwise, if the tests fail to reject the null hypothesis, the relative price series will follow a random walk (Fan and Wei, 2006).

The first stage of the time series based tests of price convergence utilises some form of unit root test, for example the Augmented Dickey-Fuller (ADF) test. In our particular example we are interested in testing for integration of the relevant energy market across the major Chinese cities, by testing for price convergence. Tests that suggest the relative price series

[$p_{ijt} = \ln(g_{ij,t} / g_{j.t})$] are stationary will provide some evidence of convergence, either absolute or relative. The unit root-based tests utilise a regression of the form:

$$\Delta p_{ij,t} = c_{ij} + \alpha_{ij} p_{ij,t-1} + \sum_{h}^{k} \beta_{ijh} \Delta p_{ij,t-h} + \varepsilon_{ij,t} \qquad (1)$$

Where Δ is the first-difference operator; c, α and β are the parameters to be estimated; ε is an identically independently distributed (*i.i.d*) error term; *i*, *j* and *t* refer respectively to city (i), energy product (j) and time (t). The ADF unit root test is simply the test of whether α_{ij} is negative and statistically significant. The number of lags, *k*, to be included in equation (1) for each product and city series is determined individually using the modified Hannan-Quinn criterion on a city-by-city and product-by-product bases.

All the ADF specifications include an intercept term to capture city-specific fixed effects and a time trend. Such intercept effects may cover, for instance, city-specific transportation, income levels, and local non-traded costs. The inclusion of the intercept term is also used to test whether prices converge to absolute price parity (zero mean) or relative price parity (nonzero mean) (Fan and Wei, 2006).

It is convenient to use one city as a benchmark (g_{jt}) in order to generate relative price series and conduct the ADF unit root tests.[1] Theoretically, it is possible that all of the ADF unit root tests will reject the null hypothesis no matter which city is chosen as a benchmark (g_{jt}) if the energy market is completely integrated. However, there may be apparent differences across energy products in the degree of market integration. Therefore, we firstly conduct the ADF unit root tests using one city as a benchmark to see how many tests reject the null. If the ADF unit root tests show almost all of them reject the unit root hypothesis for some energy products, it may not be necessary to further conduct the ADF unit root tests of relative price series on city-by-city basis. However, it may be more likely that the second scenario holds and most of the ADF unit root tests do not reject the null hypothesis. In this case, it can be argued that one city (or regional market) is not integrated with the benchmark city (or region), but it does not mean this city (or regional market) is not integrated with other cities (or regional markets). Therefore, we will conduct the ADF unit root tests on a city-by-city basis in these circumstances. This suggests that the markets of some products may not be

[1] We also consider and report some results where we benchmark against an average of all the city prices.

integrated nationally, but it can be integrated regionally due to, for example, transportation costs or network connections (especially for power supply markets). The city-by-city ADF unit root tests may also provide some clues as to where the regional market is located and which cities are included. If there are regional markets for coal and electricity, as the city-by-city ADF unit root tests suggest, we conduct panel data unit root tests for those groups of cities.

It is also interesting to measure the rate at which the relative price series converge to their long-run values. Ceglowski (2003) discusses the rates of convergence and their 'half-lives' using the expression, $\ln(0.5)/\ln(1+\alpha_{ij})$, where α_{ij} is a parameter to be estimated in equation (1). Since, in our case, the energy spot price data used are recorded every 10-days, the final half-lives are expressed in months by dividing the expression by 3.

Furthermore, it is also interesting to establish the direction of flows of information, embodied in prices, between energy markets and by implication, test for Granger causality. The following regression is used in this instance:

$$\Delta P_{it} = \theta_{11}\Delta P_{i,t-1} + \cdots + \theta_{1n}\Delta P_{i,t-n} + \theta_{21}\Delta P_{j,t-1} + \cdots + \theta_{2n}\Delta P_{j,t-n} - \gamma_1(P_{it-1} - \alpha P_{jt-1} - \delta) + \varepsilon_{1t} \quad (2)$$

$$\Delta P_{jt} = \theta_{31}\Delta P_{jt-1} + \cdots + \theta_{3n}\Delta P_{jt-n} + \theta_{41}\Delta P_{it-1} + \cdots + \theta_{4n}\Delta P_{it-n} - \gamma_2(P_{it-1} - \alpha P_{jt-1} - \delta) + \varepsilon_{2t} \quad (3)$$

The causality tests can be undertaken with the following null hypotheses:

$$\theta_{21} = \cdots = \theta_{2n} = \gamma_1 = 0 \quad (4)$$

Which implies there is no causality from p_j to p_i.

$$\theta_{41} = \cdots = \theta_{4n} = \gamma_2 = 0 \quad (5)$$

Which implies there is no causality from p_i to p_j.

3. Data

The data used in this empirical study are a panel data set of 10-day prices for four energy fuels in 31 major Chinese cities.[2] The price data are collected by the China Price Information

[2] The cities are Beijing, Tianjin, Shijiazhuang, Taiyuan, Huhehaote, Shenyang, Changchun, Harbin, Shanghai, Nanjing, Hangzhou, Hefei, Fuzhou, Nanchang, Jinan, Zhengzhou, Wuhan, Changsha, Guangzhou, Nanning, Haikou, Chongqing,

Center (CPIC) – a division of the State Development Planning Commission (SDPC) of the People's Republic of China. The data are used in this study are spot prices and are regularly collected on a ten-day interval (the 5th, 15th and 25th of each month) from local markets by governmental agencies.[3]

Unlike other market price data, our fuel price data have no missing data during the study period as fuels are extensively used in all cities. We use four major fuel products; coal, electricity, gasoline and diesel. These panel data are truly nationally representative because they cover the main fuel components, all provincial capital cities of mainland China, and the period, 1995 to 2005. This is to be contrasted with most other empirical studies, which use a price index of lower frequency (such as annual) data. The 10-day frequency of our price data also corresponds well to the time needed for domestic price arbitrage as a lower frequency (monthly) price data are not as useful when we wish to test for price convergence with any degree of precision (Taylor, 2001). Furthermore, monthly spot prices are not as rich a data source as 10-day spot prices, particularly if one wants to measure the half-life of subsequent adjustment following the shorter time response (Bachmeier and Griffin, 2006).

The quality of Chinese data is often criticised as reporting in China is often affected by political factors (Rawski, 2001). However, we believe that the data for specific product prices collected by local government agencies under strict government mandates are unlikely to be subject to manipulation. Central government requires the collection of prices for specific products at fixed dates and locations and these price data are also available to the public so that local officials would find it hard to report false data. Unlike macro-economic data (such as GDP growth and employment rates), these micro data for prices could hardly serve as indicators when assessing the performance of local officials and hence local officials have little incentive to falsify them.

Chengdu, Guiyang, Kunming, Lhasa, Xian, Lanzhou, Xining, Yinchuan, Urumqi. They include four municipalities and all the capital cities for the 31 provinces and autonomous regions in mainland China.

[3] The price data are collected to provide price information to the central and local governments for macroeconomic management. According to state law, the local price bureaus in 31 major cities are obligated to report price information for a specified list of products to the Price Information Center. The price information must be collected from fixed local markets. The fuel price information is collected three times a month, on the 5th, the 15th and the 25th day of the month. The fuel names are uniform across all cities, and all prices must be market prices.

4. Results and discussions

The methodology used here commences with unit root tests on the raw price data. The individual unit root test results are displayed in Appendix 1 for the individual city levels data series and Appendix 2 for the first differenced series. In summary the unit root tests show that each of the 31 city price data series for all four energy products exhibit unit roots. All the tests suggest that the first differences of the series are stationary and therefore that all series are integrated of order 1 or I(1).

4.1 Shanghai benchmark

Having established that the raw price series each contain a unit root, we next conduct the ADF unit root test for relative price series using Shanghai as a benchmark to examine whether energy prices of all other cities converge with that of Shanghai. The test results are shown in Table 1.

Table 1 shows that for coal, 9 of the 31 relative price series are significant at the 5% level which means that few of the city price series show convergence in the case of coal. For electricity, there are only two relative price series that reject the null hypothesis and indicate convergence. However, for gasoline and diesel the opposite is true. Here, all but six (Tianjin, Hangzhou, Nanning, Changsha [noted still at the 5.6% level], Chongqing, and Lhasa) of the ADF unit root tests show rejection at above 5% level for the gasoline relative price series. Likewise, almost the same is observed for diesel. In particular, there are 19 relative price series that reject the null hypothesis at the 5% level, accounting for approximately 60% of the total of 31 diesel relative series. In addition, there are three relative price series that reject the null hypothesis close to the 5% level (Jinan, Nanning and Chengdu) and four at the 10% level (Shijiazhuang, Huhehaote, Hangzhou and Urumqi). This means all but four (Hefei, Guangzhou, Kunming and Lhasa) of the ADF unit root tests show rejection at above 10% level for diesel.

At this stage we can see that gasoline and diesel prices show strong convergence with Shanghai. If we take account of some special and remote regions (e.g., Lhasa, Urumqi, Kunming), almost all gasoline and diesel prices series are convergent with each other.

Therefore, we are able to conclude that the gasoline and diesel markets in China are integrated. This finding is generally consistent with that in Fan and Wei (2006), the only difference is that this study shows observed prices of more cities to be convergent, which may be due to the unique features of the data we utilise.

However, for the coal and electricity markets we cannot conclude that they are nationally integrated because only some (for coal) and a few (for electricity) pairs of relative price series demonstrate convergence. Moreover, we are unable to identify the reasons either due to commodity-specific characteristics (e.g., volume and network connection) or due to human intervention (e.g., local or regional trade barriers and central priority policies for some special cities or specific economic zones, such as Beijing, Shanghai, Shenzhen, etc). However, there may be some regionally integrated markets for coal and electricity because it is possible for those insignificant series to be convergent with those of its neighbours instead of convergent with Shanghai. In effect, we may have 'local convergence' akin to the 'convergence clubs' found in the macroeconomic literature. To test for the possible existence of local convergence we extend the research in two important ways. Firstly, we apply the same unit root testing procedure on a 'city-by-city' basis to test whether there are regional markets for coal and electricity. These city-by-city unit root test results are presented as Table 2 for coal and Table 3 for electricity. Secondly, we undertake panel-based unit root tests on a group of cities using an average of a group of city prices as a benchmark to test whether the group of cities identified above as convergent, are regionally integrated. These results are presented as Table 4.

4.2 City-by-city convergence

Firstly, consider the city-by-city results presented as Table 2, which show that there are 65 pairs of relative price series that reject the null hypothesis of a unit root (non-convergence) at the 5% level, accounting for 14% of total (465) pairs of relative price series.[4] In particular, there are 12-13 pairs of relative price series that reject the null hypothesis for Shijiazhuang (code 3), Nanning (code 20) and Chongqing (code 22). There are 7-10 pairs of relative price

[4] In this study, we choose significant at the 5% level. At the 10% level there are 111 pairs of relative price series which reject the null hypothesis, accounting for 24% of the total of (465) pairs.

series that reject the null hypothesis for five cities, which are Beijing (code 1), Huhehaote (code 5), Shanghai (code 9), Wuhan (code 17), Chengdu (code 23) and Xian (code 27).

It is interesting to note that the coal price in Taiyuan (code 4), which is located in Shanxi province, the largest coal production base and accounting for approximate 20% of national coal supply, is not significantly convergent[5] with the coal price of its neighbors, Huhehaote (code 5), which is located in Inner Mongolia autonomous region, the second or third largest coal production area and accounting for about 10% of the national supply of coal. This suggests that the coal price in Taiyuan is not convergent with the coal price in the production area. However, for Huhehaote it seems the opposite holds as its coal price is convergent with that of most of its neighbors (Shijiazhuang, Taiyuan and Changchun) and south towards Jinan, Wuhan, Changsha and Shanghai.

If we consider columns 3, 20 and 22 in more detail, we are able to identify regional energy markets and their locations. For example, the first starts from Shijiazhuang (code 3), which converges with those of its neighbors: Beijing (code 1), Huhehaote (code 5), Shenyang (code 6) and Zhengzhou (code 16). It extends southeast to Hefei (code 12) and Shanghai (code 9), and southwest to Xian (code 27) and Wuhan (code 17) and might extend further to the west to include Chongqing (code 22) and Chengdu (code 23). It therefore covers approximately eleven cities and is geographically located in north, central and central west China. Its track is generally from northeast to southwest and 'bends' to the southeast. Also following convergent lines, Nanning (code 20) and Chongqing (code 22), comprise the second coal market beginning at the east coast, Shanghai (code 9) and Hangzhou (code 11), moving west first towards Hefei (12) and Nanchang (code 14), then towards Wuhan (code 17) and Changsha (code 18). From there it moves further west to Chongqing (code 22), Chengdu (code 23) and Xian (code 27) and south towards Nanning (code 20) and Guangdong (code 19). This area covers eleven cities, which are located in the central west, central south, central east and south of China.[6] The general shape looks like a triangle, the top angle is located in Shanghai and Zhejiang, two bottom angles are located in southwest (Sichuan and Chongqing) and south (Guangxi and Guangdong).

[5] Because their p-value is 5.7% and insignificant based the criterion used in this study.
[6] It should be noted that some cities may be included in different markets.

Moving to the results on electricity presented as Table 3, there appear to be fewer examples of convergence. In particular, there are 38 pairs which reject the null hypothesis, which account for 8.2% of the total (465) pairs of relative price series. There are only four cities; Nanchang (code 14), Zhengzhou (code 16), Haikou (21) and Lhasa (26) that have 8-10 pairs of relative price series which reject the null at the 5% level. In addition, fewer pairs of relative price series can be found to be convergent in the major cities. For example, none of the pairs identified reject the null for Beijing (code 1) and Guangzhou (code 19). One pair rejects the null for Nanjing (code 10) and Hangzhou (code 11). Two pairs reject the null for Shanghai (code 9) and Jinan (code 14). Therefore, it seems less likely that the electricity market can be described as 'regionally integrated' as was argued above for coal. However, we found that there are 111 pairs which do reject the null hypothesis if the level of significance is raised to the 10% level, accounting for 24% of total 465 pairs of relative price series. We also found that the annual standard deviation coefficients have fallen since 1995. For example, it is 29.3% in 1995, 25.6% in 2000 and only 8.9% in 2005.[7]

In sum, based upon the city-by-city unit root tests we cannot conclude that the coal and electricity markets are nationally integrated although we have found some evidence of 'within region' convergence.

4.3 Panel unit root tests of convergence

Next, we use panel unit root tests which are less likely to suffer from multiple testing issues and potentially size distortion as such tests are known to have greater power (Banerjee, 1999; Maddala and Wu, 1999). Therefore, to test whether a group of cities belong to a certain regional market, we use panel-based unit root tests as an alternative to the city-by-city approach. We conduct two types of panel-based unit root tests. One is for the group of cities that were previously identified as belonging to the same coal regional market. Another is for the group of all cities for electricity, gasoline and diesel markets to demonstrate that the electricity market is not nationally integrated and the oil markets are nationally integrated as discussed previously.

[7] Annual standard deviation coefficients are calculated by $[\sum(p_{it}-\overline{p}_t)^2/(n-1)]^{0.5}/\overline{p}_t \times 100\%$, where p_{it} stands for price for city *i* in year t, $\overline{p}_t$ stands for average price in year t, n is sample size (here is 31).

From Table 4, first we are able to conclude that both the coal regional market I and II identified in the last section show convergence. Second, although two coal regional markets are identified, they are very close geographically and partly merge together, which may imply that both of them are also integrated and belong to a greater regional market. We can conclude, based on Table 4, that both of the coal regional markets actually belong to the same greater market, there defined as market III. In this case, if we ignore the remote cities (due to transportation cost) and small regional economies which are much less likely to consume large volumes of coal, most of cities in China might be regarded as belonging to one integrated coal market as most appear to 'converge' to each other via a network of adjacent prices. Third, the groups of all cities for gasoline and diesel prices also show convergence, which further confirms our conclusion that both the gasoline and diesel markets are nationally integrated in China. Finally, as for a national electricity market, the results not only do not reject the most restrictive test at the 5% level, but they do not reject either of the Im, Pesaran and Shin or Fisher Chi-square tests. This probably means that the electricity market in China is not integrated.

4.4 Absolute versus Relative Price Convergence

To test for Absolute versus Relative price convergence we make use of the significance of the intercept term in equation (1) in the cases where the series indicate convergence. The 'test on the intercept results' are also shown in Tables 2 and 3 for coal and electricity, respectively. The highlighted stars in Tables 2 and 3 indicate that the intercept terms in equation (1) are insignificant, which implies that prices are convergent to absolute price parity. Otherwise, the unhighlighted stars in table 2 and 3 indicate that the prices converge to relative price parity. Table 2 shows that there are 13 intercept terms (highlighted) insignificant at or above the 5% level, accounting for 20% of the total of 65 pairs of convergent series for coal. In other words, among the convergent series, only 20% converge to absolute price parity and 80% converge to relative price parity. Similarly, for electricity there are 24 pairs, accounting for 63% of the total of convergent series, that suggest absolute price parity and only 37% relative price parity (Table 3). In addition, the observed magnitudes of the significantly different from zero estimated intercept terms (c) for coal and electricity price, are all very small. This suggests that the price ratios of two cities are close to unity in terms of intercept terms.

4.5 Estimated 'half-lives' to convergence

Using the expression $\ln(0.5)/\ln(1+\alpha_{ij})$ and the estimated α_{ij} in equation (1), we calculated half-lives for those relative price series that reject the null hypothesis. The results are presented as Table 5 for coal and Table 6 for electricity. The overall average rate is approximately 3.4 months, implying that it takes 3.4 months for coal relative prices to converge to their long-run values. The estimated half-lives vary little, the minimum rate is 1.4 months and the maximum is 6.2 months, and most fall in the range 2.0 to 4.5 months. For electricity, the overall average rate is smaller, 2.2 months, implying that it takes 2.2 months for electricity relative prices to converge to their long-run values. The estimated half-lives also vary little, the minimum rate is 1.2 months and the maximum is 4.2 months, and most fall in the range 2.0 to 4.0 months.

Turning now to gasoline, Table 7 reports results on the rate of convergence to long-run values. Here we find that 186 pairs of relative price series converge to absolute price parity, accounting for 78% of the total of 238 pairs of relative price series which reject the null hypothesis of non-convergence. Three cities where price convergence is well established are Jinan (code 15), Kunming (code 25) and Xining (code 29). Here the results suggest that prices in these three cities converge to absolute price parity with more than 20 other cities. Results for Shijiazhuang (code 3), Shanghai (code 9), Changsha (code 18), Chengdu (code 23) and Guiyang (code 24), suggest that the relative price series are convergent to absolute price parity with more than half of the other cities. Turning to the convergence rate, we find that the rates are much faster than those of coal and electricity prices. In particular, the overall average rate is estimated to be 1.7 months, which is a little higher than that estimated by Fan and Wei (2006) where their estimate is 1.3 months. The maximum rate is approximately 4.9 months, while the minimum rate is only 0.3 months (about ten days). Approximately 10% of the convergence rates are less one month; 60% in the range 1-2 months and 27% between 2-3 months.

Table 8 presents the results for diesel. Here we find 186 pairs of relative price series that converge to absolute price parity, accounting for 82% of the total of 228 pairs of relative price series that reject the null hypothesis of non-convergence. Four cities where more than 18 relative price series converge to absolute price parity are Shenyang (code 6), Harbin (code 8), Nanchang (code 14) and Chongqing (code 22). Six cities where more than 15 relative price series converge to absolute price parity are Shijiazhuang (code 3), Changchun (code 7), Shanghai (code 9), Zhengzhou (code 16), Changsha (code 18) and Xining (code 29). Furthermore, we find that convergence rates are much faster than those of coal and electricity prices, and even smaller than those of gasoline. In particular, the overall average rate is 1.6 months, which is smaller than that estimated by Fan and Wei (2006) where their estimate is 2.3 months. The maximum rate is 2.9 months, while the minimum is only 0.6 months (about twenty days). Approximately 10% of the convergence rates are less than one month; 60% range from 1-2 months, and 27% are between 2-3 months.

4.6 Granger Causality tests

The results for tests of Granger causality between each pair of cities where the relative prices significantly converge are presented as Table 9 for coal and Table 10 for electricity. Firstly, it can be seen from Table 9 that there are approximately 46 pairs of bi-directional causality, accounting for nearly 54% of the total of 86 pairs of causal relationships for coal. However, the causal relationships vary considerably across cities. For example, Shanghai (code 9) and Nanning (code 20) have causally bi-directional relationships with 7 cities, while there are 14 cities that have no causally bi-directional relationships with others. Causality most likely originates from Shijiazhuang (code 3), which causes coal price change in 12 other cities. This is followed by Beijing (code 1), Shanghai (code 9), Wuhan (code 17), Nanning (code 20) and Chongqing (code 22), which cause coal price changes in 6-7 other cities, respectively. Observing these cities (Beijing, Shijiazhuang, Shanghai and Wuhan) where causality originates, we find that almost all coal price changes originate from consumption areas rather than production areas. However, we do find that one of the large production bases, Huhehaote (code 5), has bi-directional causal relationship. Rather puzzlingly, we do not identify causality originating either from the large consumption cities, such as Taiyuan (code 4), Nanjing (code

10), Jinan (code 15) and Zhengzhou (code 16) or from production cities, such as Taiyuan (code 4), Harbin (code 8), Jinan (code 14), Zhengzhou (code 15) and Guiyang (code 24).

Secondly, there are 65 pairs of bi-directional causality, accounting for more than 90% of the total of 71 pairs of causal relationships identified for electricity (Table 10). The origins of causality appear more mixed, but it most likely that they originate from Haikou (code 21), Nanchang (code 14) and Chengdu (code 23). However, there appear to be many more origins including Shijiazhuang (code 3), Changchun (code 7), Zhengzhou (code 16) and Changsha (code 18), that can cause electricity price change in 4-5 other cities. Considering the cities listed above, we find that electricity price changes may originate from both medium sized areas of consumption and production. It seems hard to establish that causality originates from both large consumption areas, such as Nanjing (code 10) and Guangdong (code 19) and production areas, such as Taiyuan (code 4), Hangzhou (code 11) and Jinan (code 15).

Finally, turn to the causality results for gasoline and diesel markets. The results are displayed in Tables 11 and 12. It can be seen from Tables 11 and 12 that there are different causal scenarios from those established for gasoline and diesel because, in part, there are many more pairs of convergent relative price series.

The results presented as Table 11 identify 320 pairs of bi-directional causality, accounting for nearly 90% of the total 357 pairs where causality is established in gasoline prices. However, the causal relationship is richer and varies apparently across cities. For example, Shanghai (code 9), Nanchang (code 14) and Changsha (code 18) have 18-19 bi-directional causality relationships with other cities. Shijiazhuang (code 3), Huhehaote (code 5), Jinan (code 15), Chengdu (code 23) and Guiyang (code 24) have 15-17 bi-directional causal relationships with other cities. The causality most likely originates from Shanghai (code 9), Nanchang (code 14) and Changsha (code 18), then Shijiazhuang (code 3), Huhehaote (code 5), Nanjing (code 10), Jinan (code 15), Wuhan (code 17) Haikou (code 21), Chengdu (code 23), Guiyang (code 24) and Yinchuan (code 30). We cannot identify whether causality originates from consumption cities or from production cities because most of cities in China do not produce gasoline.

Table 12 presents the causality results for diesel. Here 409 pairs of bi-directional causality are established, accounting for approximately 95% of the total of 432 pairs of causal relationships identified. Again, the causal relationships vary across cities. For example, Shenyang (code 6), Harbin (code 8) and Chongqing (code 22) have over 20 bi-directional causality relationships with others cities. Taiyuan (code 4), Changchun (code 7), Fuzhou (code 13), Nanchang (14), Zhengzhou (code 16) and Changsha (code 18) have 18-19 bi-directional causality relationships with others. The causality also most likely originates from Shenyang (code 6), Harbin (code 8), Fuzhou (code 13) and Chongqing (code 22), then from Taiyuan (code 4), Changchun (code 7), Nanchang (code 14), Zhengzhou (code 16), Wuhan (code 17) and Changsha (code 18). As with gasoline, we cannot identify whether causality originates from consumption or producing areas because most of cities in China do not produce diesel.

5. Conclusions

The paper investigates energy market integration in China utilizing a range of time series econometric methods and a new, high frequency energy price data set. The results presented here identify price series that converge to absolute or relative price parity and calculate the rates at which relative prices converge to their long-run values. In addition, the paper analyzed 'causal' relationships between prices across cities and sought to identify the most likely origins. In summary the major findings comprise the following.

First, unit root tests show that gasoline and diesel markets are generally well integrated across China as most tests reject the unit root hypothesis (of non-convergence) when applied to relative prices. Once account is taken of some special and remote cities, it may be safe to conclude that the gasoline and diesel markets are well integrated as a whole. This finding is consistent with those of other authors.

All tests suggest, however, that the electricity markets are not as well integrated in relation to price convergence. This may be due to commodity-specific characteristics (e.g., volume and network connection) or intervention (e.g., local trade barriers and central priority policies). In the case of coal, city-by-city unit root tests suggest some regionally integrated markets. If we ignore the remote cities (due to transportation costs) and small regional economies which are much less likely to consume large volumes of coal, most of cities in China might be regarded as belonging to one integrated coal market as most appear to 'converge' to each other via a network of adjacent prices.

Secondly, we find that the estimated intercept terms are all very small and close to zero in spite of their significance. Therefore, the price ratios of two cities are more likely close to unity. As a result, most of relative price series may be regarded as convergent to absolute price parity. This is particularly true for oil market prices.

Thirdly, the rates at which relative prices converge to their long-run values vary little and are even faster compared with that found in other countries. For example, the rate of convergence for U.S. coal markets ranges from more 6 months to more than 13 months (Bachmeier and Griffin, 2006). However, the rate of convergence found here for China's coal market is, on average, only about 3.4 months.

Fourthly, a rich set of causality relationships appear to exist between cities. Many results suggest bi-directional causality, so it is hard to establish the geographic source of price changes. However, for coal and electricity it appears that both demand and supply cities show some impact on the source of the observed price changes.

Eventually, the paper has made some important inroads into analyzing and testing the degree and pervasiveness of energy market price integration in China by examining the time series convergence properties of the relative price of four major energy inputs, coal, electricity, gasoline and diesel. Given previous work and a priori expectations, the results for gasoline and diesel were unsurprising, although their robustness utilizing a new and exciting dataset were reassuring. The results on electricity and coal, however, suggest more work is required to identify whether commodity specific factors or intervention are the source of (at best) regional market integration or regional 'price convergence'.

References:

1. Adrangi, B., Chatrath, A., Raffiee, K., Ripple, R.D., 2001. Alaska North Slope crude oil price and the behavior of diesel prices in California. *Energy Economics* 23, 29– 42.
2. Asche, F., GjØlberg, O., VÖlker T., 2003. Price relationships in the petroleum market: an analysis of crude oil and refined product prices. *Energy Economics* 25, 289– 301.
3. Asche, F., Osmunddsen, P., Sandssmark, M., 2006. The UK market for natural gas, oil and electricity: are the prices decoupled? *The Energy Journal* 27 (2), 27–40.
4. Asche, F., Osmundsen, P., Tveterås, R., 2002. European market integration for gas volume flexibility and political risk. *Energy Economics* 24, 249–265.
5. Bachmeier, L.J., Griffin, J.M., 2006. Testing for market integration: crude oil, coal, and natural gas. *The Energy Journal* 27, 55–71.
6. Banerjee, Anindya, 1999. Panel data unit roots and cointegration: an overview. *Oxford Bulletin of Economics and Statistics* 61, 607-629.
7. Bentzen, J., 2003. An empirical analysis of gasoline price convergence for 20 OECD countries. WORKING PAPER 03-19. Department of Economics, Aarhus School of Business, Denmark.
8. Bernard, A.B., Durlauf, S.N., 1996. Interpreting tests of the convergence hypothesis. *Journal of Econometrics* 71, 161–173.
9. Ceglowski, J., 2003. The law of one price: intranational evidence for Canada. *Canadian Journal of Economics* 36, 373-400.
10. De Vany, A.S., Walls,W.D., 1999. Cointegration analysis of spot electricity prices: insights on transmission efficiency in the western US. *Energy Economics* 21, 435–448.
11. Fan, C. S., Wei X., 2006. The law of one price: evidence from the transitional economy of China. *The Review of Economics and Statistics*. 88(4): 682-697.
12. Girma, P., Paulson, A., 1999. Risk arbitrage opportunities in petroleum futures spreads. *Journal of Future Markets* 19, 931–955.
13. Gjolberg, O., Johnsen, T., 1999. Risk management in the oil industry: can information on long-run equilibrium prices be utilized? *Energy Economics* 21, 517– 527.
14. Greasley, D., Oxley, L., 1997. Time-series based tests of the convergence hypothesis: some positive results. *Economic Letters* 56, 146–147.
15. Lanza, A., Manera M., Giovannini M., 2005. Modeling and forecasting cointegrated relationships among heavy oil and product prices. *Energy Economics* 27, 831– 848.
16. Lau, L.J., Qian Y.Y., Gerard R., 2000. Reform without losers: an interpretation of China's dual-track approach to transition. *Journal of Political Economics* 108, 120-143.
17. Maddala, G. S., Wu, S.W., 1999. A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, 61: 631-652.
18. Narayan, P.K., Smyth, R., 2005. The residential demand for electricity in Australia: an application of the bounds testing approach to cointegration. *Energy Policy* 33, 467–474.
19. Poncet, S., 2003. Measuring Chinese domestic and international integration. *China Economic Review* 14, 1-21.
20. Poncet, S., 2005. A fragmented China: measure and determinants of Chinese domestic market disintegration. *Review of International Economics*. 13(3):409-430.
21. Rawski, T.G., 2001. What is happening to China's GDP statistics? *China Economic Review* 12, 347–354.
22. Serletis, A., 1994. A integration analysis of petroleum futures prices. *Energy Economics* 16, 93– 97.

23. Shaked, A., Sutton, J., 1982. Relaxing price competition through product differentiation. *Review of Economic Studies* 49, 3 – 13.
24. Stern, D.I., 2000. A multivariate cointegration analysis of the role of energy in the US macroeconomy. *Energy Economics* 22, 267-283.
25. Taylor, A. M., 2001. Potential pitfalls for the purchasing-power-parity puzzle? Sampling and specification biases in mean-reversion tests of the law of one price. *Econometrica* 69, 473-498.
26. Terry, R., 2007.Have European gas prices converged? *Energy Policy* 35, 2347–2351.
27. Weiner, R., 1991. Is the world oil market done great pool? *The Energy Journal* 12, 95–107.
28. Wyeth, J., 1992. The measurement of market integration and applications to food security policies. Discussion Paper No 314, Institute of Development Studies, University of Sussex, Brighton.
29. Young, A., 2000. The razor's edge: distortions and incremental reform in the People's Republic of China. *The Quarterly Journal of Economics* CXV, 1091-1135.
30. Zhou, Z.Y., Wan, G.H., Chen, L.B, 2000.Integration of rice market: the case of southern China. *Contemporary Economic Policy* 18, 95-106.

Table 1. Unit root tests for relative price series (Shanghai is used as a benchmark)

Province	City	Code	Coal		Electricity		Gasoline		Diesel	
			t-stat.	Prob.*	t-stat.	Prob.*	t-stat.	Prob.*	t-stat.	Prob.*
Beijing	Beijing	1	-2.81	**0.058**	-1.68	0.441	-3.14	**0.025**	-3.21	**0.020**
Tianjin	Tianjin	2	-1.09	0.723	-1.59	0.486	-2.36	0.153	-2.87	**0.050**
Hebei	Shijiazhuang	3	-3.95	**0.002**	-1.92	0.321	-5.21	**0.000**	-2.72	0.071
Shanxi	Taiyuan	4	-1.87	0.347	-1.20	0.674	-4.29	**0.001**	-4.24	**0.001**
Mongolia	Huhehaote	5	-3.54	**0.007**	-2.63	**0.088**	-3.99	**0.002**	-2.66	0.081
Liaoning	Shenyang	6	-1.30	0.630	-1.38	0.593	-3.25	**0.018**	-5.12	**0.000**
Jilin	Changchun	7	-1.98	0.295	-2.83	**0.055**	-3.58	**0.007**	-3.40	**0.012**
Heilongjiang	Harbin	8	-2.35	0.158	-2.67	**0.081**	-3.63	**0.006**	-3.77	**0.004**
Shanghai	Shanghai	9	-	-	-	-	-	-	-	-
Jiangsu	Nanjing	10	-1.02	0.746	-2.30	0.174	-3.20	**0.021**	-2.86	**0.050**
Zhejiang	Hangzhou	11	-2.16	0.221	-1.97	0.298	-2.56	0.102	-2.61	0.092
Anhui	Hefei	12	-2.05	0.266	-1.31	0.626	-3.98	**0.002**	-2.28	0.180
Fujian	Fuzhou	13	-1.13	0.705	-1.77	0.393	-3.77	**0.004**	-3.57	**0.007**
Jiangxi	Nanchang	14	-2.24	0.192	-1.57	0.497	-5.11	**0.000**	-3.84	**0.003**
Shandong	Jinan	15	-3.70	**0.004**	-2.94	**0.042**	-3.70	**0.004**	-2.80	0.059
Henan	Zhengzhou	16	-3.35	**0.014**	-1.53	0.518	-5.52	**0.000**	-3.55	**0.007**
Hubei	Wuhan	17	-4.77	**0.000**	-1.68	0.440	-3.47	**0.009**	-3.36	**0.013**
Hunan	Changsha	18	-2.54	0.107	-2.31	0.169	-2.82	0.056	-4.08	**0.001**
Guangdong	Guangzhou	19	-2.37	0.150	-1.90	0.334	-3.81	**0.003**	-2.14	0.231
Guangxi	Nanning	20	-3.57	**0.007**	-1.36	0.601	-2.23	0.197	-2.74	0.069
Hainan	Haikou	21	-1.73	0.417	-3.84	**0.003**	-5.57	**0.000**	-3.38	**0.012**
Chongqing	Chongqing	22	-3.44	**0.010**	-1.82	0.371	-2.49	0.118	-4.46	**0.000**
Sichuan	Chengdu	23	-2.93	**0.043**	-2.46	0.127	-3.68	**0.005**	-2.78	0.061
Guizhou	Guiyang	24	-1.35	0.607	-2.07	0.257	-3.86	**0.003**	-4.66	**0.000**
Yunnan	Kunming	25	-3.09	**0.028**	-1.58	0.493	-3.71	**0.004**	-2.27	0.181
Tibet	Lhasa	26	-0.90	0.788	-2.27	0.184	-1.88	0.343	-2.03	0.273
Shaanxi	Xian	27	-2.58	**0.099**	-1.82	0.371	-3.23	**0.019**	-3.13	**0.026**
Gansu	Lanzhou	28	-1.53	0.519	-1.76	0.399	-5.59	**0.000**	-3.30	**0.016**
Qinghai	Xining	29	-2.51	0.114	-1.28	0.640	-4.86	**0.000**	-4.23	**0.001**
Ningxia	Yinchuan	30	-2.57	0.100	-1.37	0.596	-4.88	**0.000**	-3.93	**0.002**
Xinjiang	Urumqi	31	-2.26	0.186	-1.50	0.535	-3.22	**0.020**	-2.60	0.093
% of rejecting null			-	9/31	-	2/31	-	25/31	-	19/31

*MacKinnon (1996) one-sided p-values.
Null hypothesis is that each relative price series contains a unit root.
ADF is the Augmented Dickey-Fuller test.
Critical values: -3.44 (1% level), -2.87 (5% level) and -2.57(10% level).

Table 2. Unit root tests for pairs of coal relative price series for those rejecting null significant at 5% (*) and 1% (**) level (highlighted stars indicate convergent to absolute price parity and the rest to relative price parity)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		-	**	-	-	-	-	-	-	-	-	*	-	-	-	**	-	-	-	**	-	*	**	-	-	-	*	-	-	-	-
2	-		-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	**	-		-	*	**	-	-	**	-	-	**	-	-	-	**	*	-	*	**	-	*	*	-	-	-	*	-	-	-	-
4	-	-	-			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	*			-	*	-	**	-	-	-	-	-	*	-	**	**	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	**	-	-		-	*	-	-	*	-	-	-	-	-	-	-	-	**	-	-	-	-	-	-	*	-	-	-	-
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11	-	-	-	-	-	*	-	-	-	-		-	-	-	-	-	-	-	-	**	-	-	-	-	-	-	**	-	*	-	-
12	*	-	**	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	**	-	**	**	-	-	-	-	-	-	-	-
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Table 3. Unit root tests for pairs of electricity relative price series for those rejecting null significant at 5% (*) and 1% (**) level (highlighted stars indicate convergent to absolute price parity and the rest to relative price parity)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-		-	**	-	-	-	-	-	-	-	-	-	-	*	-	*	-	-	-	-	**	-	-	-	-	-	-	-	-
4	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-
5	-	-	**	-		-	-	-	-	*	-	-	-	*	-	*	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-
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25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	**	-	*	-	-	-	-	**	-	*	-	-		-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	-	*	-	-		**	-	-	-
28	-	-	-	-	-	-	-	-	-	-	*	-	-	-	-	-	*	-	-	-	-	-	-	*	-	-	**		-	-	-
29	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
30	-	-	-	-	-	*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Table 4. Panel data unit root tests for identified regional or national markets (group average is used as a benchmark)

Panel unit root tests (assumption)	Regional coal market I		Regional coal market II		Regional coal market III		National gasoline market		National diesel market		National electricity market	
	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.	Stat.	Prob.
Im, Pesaran and Shin	-4.5	0.00	-4.7	0.00	-5.7	0.00	-14.2	0.00	-8.3	0.00	-0.8	**0.21**
ADF - Fisher Chi-square	61.0	0.00	66.1	0.00	97.4	0.00	359	0.00	205	0.00	60.2	**0.54**

Note: Exogenous variables are individual effects and linear trend and null hypothesis is unit root (individual unit root process). Regional coal market I includes cities 1, 3, 5, 6, 9, 12, 16, 17, 22, 23 and 27; Regional coal market II includes cities 9, 11, 12, 14, 17, 18, 19, 20, 22, 23 and 27; Regional coal market III includes I and II; National markets include all cities.

Table 5. The estimated half-lives for coal (months) for those rejecting null hypothesis (unit root) at 5% and 1% significant level

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		-	3.6	-	-	-	-	-	-	-	-	3.1	-	-	-	3.3	-	-	-	2.2	-	4.4	3.0	-	-	-	5.3	-	-	-	-
2	-		-	-	-	-	-	-	-	-	-	-	3.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	3.6	-		-	3.1	3.7	-	-	2.1	-	-	2.8	-	-	-	3.4	4.3	-	3.2	1.7	-	5.6	5.3	-	-	-	4.9	-	-	-	-
4	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	3.1	-		-	3.2	-	1.9	-	-	-	-	-	3.0	-	1.9	2.1	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	3.7	-	-		-	2.1	-	-	5.2	-	-	-	-	-	-	-	-	1.7	-	-	-	-	-	-	4.2	-	-	-	-
7	-	-	-	-	3.2	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	2.1	-		-	-	-	-	-	-	-	-	-	-	-	2.8	-	5.9	-	-	-	-	-	-	-	-	-
9	-	-	2.1	-	1.9	-	-	-		-	-	-	-	-	1.8	2.3	1.4	-	-	2.2	-	2.8	3.6	-	2.6	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-		-	-	3.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	5.2	-	-	-	-		-	-	-	-	-	-	-	-	1.9	-	-	-	-	-	-	1.8	-	2.5	-	-
12	3.1	-	2.8	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	2.0	-	3.5	3.1	-	-	-	-	-	-	-	-
13	-	3.5	-	-	-	-	-	-	-	3.1	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	2.6	-	-	3.9	-	-	-	-	-	3.1	-	-
15	-	-	-	-	3.0	-	-	-	1.8	-	-	-	-	-		-	6.2	3.7	-	-	-	-	-	-	5.0	-	-	-	-	-	-
16	3.3	-	3.4	-	-	-	-	-	2.3	-	-	-	-	-	-		4.0	-	-	-	-	4.3	-	-	-	-	-	-	-	-	-
17	-	-	4.3	-	1.9	-	-	-	1.4	-	-	-	-	-	6.2	4.0		4.2	3.2	3.8	-	4.9	-	-	-	-	-	-	-	-	-
18	-	-	-	-	2.1	-	-	-	-	-	-	-	-	-	3.7	-	4.2		-	-	-	5.5	-	-	-	-	-	-	-	-	-
19	-	-	3.2	-	-	-	-	-	-	-	-	-	-	-	-	-	3.2	-		2.8	-	-	-	-	-	-	4.6	-	-	-	-
20	2.2	-	1.7	-	-	1.7	-	2.8	2.2	-	1.9	2.0	-	2.6	-	-	3.8	-	2.8		-	4.4	3.4	-	-	-	2.6	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	3.1	-	-	-
22	4.4	-	5.6	-	-	-	-	5.9	2.8	-	-	3.5	-	-	-	4.3	4.9	5.5	-	4.4	-		4.3	-	-	-	-	-	-	-	-
23	3.0	-	5.3	-	-	-	-	-	3.6	-	-	3.1	-	3.9	-	-	-	-	-	3.4	-	4.3		-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	2.6	-	-	-	-	-	5.0	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
27	5.3	-	4.9	-	-	4.2	-	-	-	-	1.8	-	-	-	-	-	-	-	4.6	2.6	-	-	-	-	-	-		-	2.0	-	-
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1	-	-	-	-	-	-		-	-	-
29	-	-	-	-	-	-	-	-	-	-	2.5	-	-	3.1	-	-	-	-	-	-	-	-	-	-	-	-	2.0	-		-	-
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Table 6. The estimated half-lives for electricity (months) for those rejecting null hypothesis (unit root) at 5% and 1% significant level

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.3	-	-	-	-	-	-	-	-	-		-	-	-	-
3	-	-		-	2.2	-	-	-	-	-	-	-	-	-	-	2.4	-	2.5	-	-	-	-	1.3	-	-	-	-	-	-	-	-
4	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	-	-
5	-	-	2.2	-		-	-	-	-	4.2	-	-	-	2.4	-	2.3	-	2.4	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.1	-
7	-	-	-	-	-	-		-	-	-	-	-	-	1.5	-	1.9	-	2.3	-	-	1.3	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-		-	-	-	-	-	-	2.9	-	-	-	-	-	1.8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-		-	-	-	-	-	3.0	-	-	-	-	-	1.6	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	4.2	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.6	-	-	-
12	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	3.1	-	-	-	-	-	-	-
14	-	-		-	2.4	-	1.5	-	-	-	-	-	-		-	-	-	4.0	-	-	1.5	-	1.7	-	-	1.7	-	-	-	-	-
15	-	-	-	-	-	-	-	2.9	3.0	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	2.4	-	2.3	-	1.9	-	-	-	-	-	-	-	-		-		-	-	2.2		1.8	-	-	2.7	-	-	-	-	-
17	-	2.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	2.5	1.5	-	-	-
18	-	-	2.5	-	2.4	-	2.3	-	-	-	-	-	-	4.0	-		-		-	-	-	-	1.9	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	1.3	1.8	1.6	-	-	-	-	1.5	-	2.2	-	-	-	-		2.5	-	-	-	1.9	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	2.5		2.4	-	-	-	-	-	-	-	-
23	-	-	1.3	-	-	-	-	-	-	-	-	-	-	1.7	-	1.8	-	1.9	-	-	-	2.4		-	-	2.2	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-	-	3.1	-	-	-	-	-	-	-	-	-	-		-	-	2.9	3.0	-	-	-
25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7	-	2.7	-	-	-	-	1.9	-	2.2	-	-		-	-	-	-	-
27	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.5	-	-	-	-	-	-	2.9	-	-		1.3	-	-	-
28	-	-	-	-	-	-	-	-	-	-	1.6	-	-	-	-	-	1.5	-	-	-	-	-	-	3.0	-	-	1.3		-	-	-
29	-	-	-	1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
30	-	-	-	-	-	3.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Table 7. The estimated half-lives for gasoline (month) for those rejecting null significant at above 5% level (all numbers in this table are significant at above 5% level, the highlighted converge to absolute price parity and the rest to relative price parity)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		-	1.2	2.9	1.8	-	-	1.2	2.1	-	-	-	-	2.2	-	-	-	2.5	-	-	1.2	-	2.3	2.8	1.7	-	1.4	2.3	1.1	2.0	-
2	-		-	2.8	-	1.9	1.0	-	-	2.5	-	-	-	-	-	-	-	2.4	-	-	-	1.4	-	2.5	2.2	-		-	1.6	-	-
3	**1.2**	-		1.8	1.1	-	-	1.0	1.1	2.3	-	1.8	-	1.5	2.9	1.1	1.1	1.4	-	-	1.1	-	1.9	2.1	1.7	-	0.6	1.0	1.1	0.6	1.2
4	2.9	**2.8**	**1.8**		-	-	-	-	1.7	0.7	-	1.4	2.7	1.7	2.0	-	-	1.5	-	-	-	-	-	2.0	1.9	-	-	-	1.2	-	-
5	**1.8**	-	**1.1**	-		1.8	-	0.7	1.7	-	-	-	1.5	1.6	2.9	0.8	0.7	1.8	-	-	1.5	-	2.0	2.2	1.7	-	1.0	1.1	1.0	0.9	-
6	-	**1.9**	-	-	1.8		1.1	-	1.6	-	-	-	-	1.3	2.9	-	-	-	-	-	-	1.1	1.4	1.2	1.7	-	-	1.6	1.2	-	-
7	-	**1.0**	-	-	-	**1.1**		-	1.1	1.5	-	-	-	1.0	-	1.3	-	-	-	-	-	0.9	2.0	1.2	1.9	-	-	-	1.3	-	-
8	**1.2**	-	**1.0**	-	**0.7**	-	-		1.3	-	-	-	1.0	-	-	0.8	1.3	1.7	-	-	1.2	-	-	-	1.7	-	-	-	1.1		-
9	**2.1**	-	**1.1**	1.7	**1.7**	**1.6**	1.1	**1.3**		2.1	-	1.6	2.0	1.2	2.9	0.8	1.6	-	2.4	-	0.9	-	2.0	2.0	2.1	-	0.9	1.1	1.3	1.2	1.7
10	-	**2.5**	2.3	**0.7**	-	-	1.5	-	2.1		1.6	-	-	1.6	2.1	-	-	1.9	1.6	1.4	-	-	-	1.6	2.0	-	-	-	1.2	2.5	-
11	-	-	-	-	-	-	-	-	-	**1.6**		-	-	-	2.1	-	-	-	0.9	0.8	-	-	-	3.1	-	-	-	-	1.4	-	-
12	-	-	1.8	**1.4**	-	-	-	-	1.6	-	-		-	-	3.0	-	1.9	1.3	2.9	-	-	-	-	-	2.0	-	1.7	-	1.4	2.1	-
13	-	-	-	2.7	**1.5**	-	-	1.0	**2.0**	-	-	-		-	-	-	1.5	2.4	-	-	-	-	-	-	1.7	-	-	-	1.0	1.5	-
14	**2.2**	-	**1.5**	1.7	1.6	**1.3**	**1.0**	-	1.2	1.6	-	-	-		2.6	0.9	1.3	1.8	-	-	1.4	-	1.8	1.6	1.9	-	0.9	1.1	1.2	1.7	1.5
15	-	-	**2.9**	**2.0**	**2.9**	**2.9**	-	-	**2.9**	**2.1**	**2.1**	**3.0**	-	**2.6**		2.8	3.1	2.7	1.5	1.9	3.4	3.2	2.3	-	1.8	-	2.9	3.2	1.0	2.9	-
16	-	-	**1.1**	-	**0.8**	-	**1.3**	**0.8**	**0.8**	-	-	-	-	**0.9**	**2.8**		0.6	0.8	-	-	0.9	-	-	-	1.9	-	0.5	0.5	1.1	0.5	-
17	-	-	**1.1**	-	0.7	-	-	**1.3**	**1.6**	-	-	1.9	1.5	1.3	**3.1**	**0.6**		1.4	-	-	1.7	-	2.3	2.5	1.8	-	0.9	1.0	1.1	1.0	-
18	**2.5**	**2.4**	**1.4**	1.5	**1.8**	-	-	**1.7**	-	1.9	-	1.3	2.4	**1.8**	**2.7**	**0.8**	**1.4**		2.3	-	-	-	2.5	2.2	2.2	-	4.9	1.4	1.3	1.4	1.9
19	-	-	-	-	-	-	-	-	2.4	**1.6**	**0.9**	**2.9**	-	-	**1.5**	-	-	**2.3**		1.0	-	-	-	-	-	-	-	-	1.5	-	-
20	-	-	-	-	-	-	-	-	-	1.4	0.8	-	-	-	**1.9**	-	-	-	1.0		-	-	-	-	2.2	-	-	-	1.3	-	-
21	**1.2**	-	1.1	-	**1.5**	-	-	**1.2**	**0.9**	-	-	-	-	1.4	**3.4**	**0.9**	**1.7**	-	-	-		-	2.1	2.5	1.9	-	-	-	1.2	1.5	1.2
22	-	**1.4**	-	-	-	**1.1**	0.9	-	-	-	-	-	-	-	**3.2**	-	-	-	-	-	-		2.4	1.6	2.0	-	-	-	1.3	-	-
23	**2.3**	-	**1.9**	-	**2.0**	**1.4**	**2.0**	-	**2.0**	-	-	-	-	**1.8**	**2.3**	-	**2.3**	**2.5**	-	-	**2.1**	**2.4**		-	1.7	3.8	1.4	2.1	1.0	2.6	2.5
24	**2.8**	**2.5**	**2.1**	2.0	**2.2**	**1.2**	**1.2**	-	**2.0**	1.6	**3.1**	-	-	**1.6**	-	-	**2.5**	**2.2**	-	-	**2.5**	**1.6**	-		1.8	2.8	1.7	1.9	1.1	2.5	2.4
25	**1.7**	**2.2**	**1.7**	**1.9**	**1.7**	**1.7**	**1.9**	**1.7**	**2.1**	2.0	-	**2.0**	**1.7**	**1.9**	**1.8**	**1.9**	**1.8**	**2.2**	-	**2.2**	**1.9**	**2.0**	**1.7**	1.8		2.0	1.9	1.8	0.3	1.8	1.7
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	**3.8**	2.8	**2.0**		-	-	1.3	-	-
27	**1.4**	-	**0.6**	-	1.0	-	-	-	**0.9**	-	-	1.7	-	**0.9**	**2.9**	**0.5**	**0.9**	**4.9**	-	-	-	-	**1.4**	1.7	**1.9**	-		0.5	1.1	0.6	1.1
28	**2.3**	-	**1.0**	-	1.1	**1.6**		-	1.1	-	-	-	-	**1.1**	**3.2**	**0.5**	**1.0**	**1.4**	-	-	-	-	**2.1**	1.9	**1.8**	-	**0.5**		1.1	1.1	-
29	**1.1**	**1.6**	**1.1**	**1.2**	1.0	**1.2**	**1.3**	**1.1**	**1.3**	1.2	**1.4**	**1.4**	1.0	**1.2**	**1.0**	**1.1**	**1.1**	**1.3**	**1.5**	**1.3**	**1.2**	**1.3**	**1.0**	1.1	0.3	**1.3**	**1.1**	**1.1**		1.1	1.1
30	**2.0**	-	**0.6**	-	0.9	-	-	-	**1.2**	2.5	-	2.1	**1.5**	**1.7**	**2.9**	**0.5**	**1.0**	**1.4**	-	-	**1.5**	-	**2.6**	2.5	1.8	-	**0.6**	**1.1**	**1.1**		-
31	-	-	1.2	-	-	-	-	-	1.7	-	-	-	-	1.5	-	-	-	1.9	-	-	1.2	-	2.5	2.4	1.7	-	1.1	-	**1.1**	-	

Table 8. The estimated half-lives for diesel (month) for those rejecting null significant at above 5% level (all numbers in this table are significant at above 5% level, the highlighted converge to absolute price parity and the rest to relative price parity)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		-	1.8	2.0	2.5	1.9	2.1	1.3	2.5	-	-	-	1.2	-	-	1.5	2.3	-	-	-	-	2.8	1.2	1.3	1.3	-	-	-	1.4	1.1	-
2	-		-	-	-	-	0.7	-	1.9	1.3	1.7	-	2.5	-	-	2.0	-	1.4	1.3	-	-	1.8	-	-	-	-	1.7	-	-	-	-
3	1.8	-		2.0	1.8	1.4	1.2	0.8	-	-	-	-	2.1	-	-	1.5	2.4	-	-	-	-	2.5	1.4	0.7	-	-	1.5	0.9	1.3	0.7	1.4
4	2.0	-	2.0		-	1.0	1.1	-	1.3	1.0	1.5	1.3	1.7	0.9	1.5	1.1	1.0	1.5	1.8	-	-	1.3	2.1	1.6	-	-	0.8	1.5	-	1.5	-
5	2.5	-	1.8	-		2.3	-	1.5	-	-	-	-	1.5	-	-	-	-	-	-	-	-	2.7	2.2	2.9	-	-	-	2.1	2.3	-	-
6	1.9	-	1.4	1.0	2.3		1.1	1.3	1.2	1.7	1.9	-	1.4	1.4	1.5	1.3	1.3	1.2	-	-	-	1.8	1.6	1.3	1.8	-	1.0	1.3	1.1	0.9	-
7	2.1	0.7	1.2	1.1	-	1.1		0.9	1.2	1.5	-	-	1.9	1.3	1.7	1.1	1.2	1.4	-	-	-	1.7	1.9	1.0	-	-	1.1	1.0	-	-	-
8	1.3	-	0.8	-	1.5	1.3	0.9		1.7	-	-	2.0	1.3	1.6	1.7	1.0	1.6	2.0	-	-	2.1	2.6	1.2	0.7	1.1	2.0	1.0	0.7	1.1	0.8	1.5
9	2.5	1.9	-	1.3	-	1.2	1.2	1.7		-	-	-	2.3	1.5	-	0.9	1.5	1.1	-	-	1.4	1.8	-	1.2	-	-	1.4	2.0	1.2	1.4	-
10	-	1.3	-	1.0	-	1.7	1.5	-	-		1.3	-	-	1.6	-	-	-	1.6	1.2	1.8	-	1.5	-	-	-	-	-	-	-	-	-
11	-	1.7	-	1.5	-	1.9	-	-	-	1.3		-	-	-	2.9	-	-	-	1.2	1.0	-	2.0	-	-	-	-	2.2	-	-	-	-
12	-	-	-	1.3	-	-	-	2.0	-	-	-		-	1.1	-	-	-	-	-	-	0.9	1.4	-	-	-	-	-	-	-	-	-
13	1.2	2.5	2.1	1.7	1.5	1.4	1.9	1.3	2.3	-	-	-		-	-	1.7	1.6	-	-	-	1.8	1.8	1.7	1.4	2.0	2.7	-	-	1.9	1.2	2.7
14	-	-	-	0.9	-	1.4	1.3	1.6	1.5	1.6	-	1.1	-		-	1.1	1.2	1.7	2.1	2.7	1.1	1.6	-	1.6	-	-	1.0	-	1.5	1.6	2.5
15	-	-	-	1.5	-	1.5	1.7	1.7	-	-	2.9	-	-	-		-	2.5	2.6	-	-	-	1.9	1.6	1.8	-	-	1.4	-	1.2	1.0	-
16	1.5	2.0	1.5	1.1	-	1.3	1.1	1.0	0.9	-	-	-	1.7	1.1	-		0.6	1.5	-	-	-	1.2	-	0.7	-	-	0.9	1.1	1.5	1.0	1.9
17	2.3	-	2.4	1.0	-	1.3	1.2	1.6	1.5	-	-	-	1.6	1.2	2.5	0.6		1.9	-	-	1.2	1.5	-	1.3	-	-	0.8	2.0	-	1.0	-
18	-	1.4	-	1.5	-	1.2	1.4	2.0	1.1	1.6	-	-	-	1.7	2.6	1.5	1.9		1.6	1.6	1.1	1.9	2.8	1.6	-	-	1.5	2.4	1.6	2.0	-
19	-	1.3	-	1.8	-	-	-	-	-	1.2	1.2	-	-	2.1	-	-	-	1.6		1.0	-	2.6	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	1.8	1.0	-	-	2.7	-	-	-	1.6	1.0		-	2.4	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	2.1	1.4	-	-	0.9	1.8	1.1	-	-	1.2	1.1	-	-		1.3	-	2.1	-	-	-	-	-	-	-
22	2.8	1.8	2.5	1.3	2.7	1.8	1.7	2.6	1.8	1.5	2.0	1.4	1.8	1.6	1.9	1.2	1.5	1.9	2.6	2.4	1.3		2.3	1.6	1.9	-	1.4	2.0	1.4	1.8	2.7
23	1.2	-	1.4	2.1	2.2	1.6	1.9	1.2	-	-	-	-	1.7	-	1.6	-	-	2.8	-	-	-	2.3		-	-	-	-	1.7	1.5	1.2	-
24	1.3	-	0.7	1.6	2.9	1.3	1.0	0.7	1.2	-	-	-	1.4	1.6	1.8	0.7	1.3	1.6	-	-	2.1	1.6	-		-	-	-	-	-	-	-
25	1.3	-	-	-	-	1.8	-	1.1	-	-	-	-	-	2.3	-	-	-	-	-	-	-	1.9	-	-		-	-	-	-	-	-
26	-	-	-	-	-	-	-	2.0	-	-	-	-	2.7	-	-	-	-	-	-	-	-	-	-	-	-		-	2.2	-	-	-
27	-	1.7	1.5	0.8	-	1.0	1.1	1.0	1.4	-	2.2	-	-	1.0	1.4	0.9	0.8	1.5	-	-	-	1.4	-	-	-	-		1.0	0.7	0.8	-
28	-	-	0.9	1.5	2.1	1.3	1.0	0.7	2.0	-	-	-	-	-	-	1.1	2.0	2.4	-	-	-	2.0	1.7	-	-	2.2	1.0		1.2	0.9	1.6
29	1.4	-	1.3	-	2.3	1.1	-	1.1	1.2	-	-	-	1.9	1.5	1.2	1.5	-	1.6	-	-	-	1.4	1.5	-	-	-	0.7	1.2		0.9	-
30	1.1	-	0.7	1.5	-	0.9	-	0.8	1.4	-	-	-	1.2	1.6	1.0	1.0	1.0	2.0	-	-	-	1.8	1.2	-	-	-	0.8	0.9	0.9		-
31	-	-	1.4	-	-	-	-	1.5	-	-	-	-	2.7	2.5	-	1.9	-	-	-	-	-	2.7	-	-	-	-	-	1.6	-	-	

Table 9. Causality among coal price series (→ stands for information flows from row to column)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		-	-	-	-	-	-	-	-	-	-	→	-	-	-	→	-	-	-	↔	-	↔	→	-	-	-	↔	-	-	-	-
2	-		-	-	-	-	-	-	-	-	-	-	→	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	→	-		-	→	→	-	-	↔	-	-	↔	-	-	-	↔	→	-	↔	↔	-	→	→	-	-	-	→	-	-	-	-
4	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-		-	↔	-	↔	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-		-	→	-	-	→	-	-	-	-	-	-	-	-	→	-	-	-	-	-	-	→	-	-	-	-
7	-	-	-	-	↔	-			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	→	-	-	-	-	-	-	-	-	-	-	-
9	-	-	↔	-	↔	-	-	-		-	-	-	-	-	↔	↔	-	-	-	↔	-	-	↔	-	↔	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-	-		-	-	→	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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15	-	-	-	-	→	-	-	-	↔	-	-	-	-	-		-	-	→	-	-	-	-	-	-	-	-	-	-	-	-	-
16	-	-	↔	-	-	-	-	-	↔	-	-	-	-	-	-		-		-	-	-		-	-	-	-	-	-	-	-	-
17	-	-	-	-	→	-	-	-	→	-	-	-	-	-	→	→		→	→	→	-	→	-	-	-	-	-	-	-	-	-
18	-	-	-	-	→	-	-	-	-	-	-	-	-	-	-	-	-				-	-	-	-	-	-	-	-	-	-	-
19	-	-	↔	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		↔	-	-		-	-	-	→	-	-	-	-
20	↔	-	↔	-	-		-	-	↔		↔	-	-	↔	-	-	-	-	↔		-	-	↔	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-		-	-	-	-	-	-	→	-	-	-
22	↔	-	-	-	-	-	-	→	→	-	-	→	-	-	-		-	→	-	→	-		-	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-	↔	-	-	↔	-	↔	-	-	-	-	-	↔	-	→		-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-		-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-	↔	-	-	-	-	-	→	-	-		-	-	-	-	-	-		-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
27	↔	-	-	-	-	-	-	-	-	-	↔	-	-	-	-	-	-	-	-	→	-	-	-	-	-	-		-	↔	-	-
28	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	↔	-		-	-
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Table 10. Causality among electricity price series (→ stands for information flows from row to column)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	↔	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	-	-		-	→	-	-	-	-	-	-	-	-	-	-	↔	-	↔	-	-	-	-	↔	-	-	-	-	-	-	-	-
4	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	→	-	-
5	-	-	-	-		-	-	-	-	↔	-	-	-	-	-	↔	-	↔	-	-	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	↔	-
7	-	-	-	-	-	-		-	-	-	-	-	-	↔	-	↔	-	↔	-	-	↔	-	-	-	-	-	-	-	-	-	-
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12	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	↔	-	-	-	-	-	-	-
14	-	-	-	-	→	-	↔	-	-	-	-	-	-		-	-	-	↔	-	-	↔	-	↔	-	-	↔	-	-	-	-	-
15	-	-	-	-	-	-	-	↔	↔	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	↔	-	-	-	-	-
16	-	-	↔	-	↔	-	↔	-	-	-	-	-	-	-	-		-	-	-	-	↔	-	↔	-	-	-	-	-	-	-	-
17	-	↔	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	↔	↔	-	-	-
18	-	-	↔	-	↔	-	↔	-	-	-	-	-	-	↔	-	-	-		-	-	-	-	↔	-	-	-	-	-	-	-	-
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	↔	↔	↔	-	-	-	-	↔	-	↔	-	-	-	-		↔	-	-	-	↔	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	↔		↔	-	-	-	-	-	-	-	-
23	-	-	↔	-	-	-	-	-	-	-	-	-	-	↔	-	↔	-	↔	-	-	-	↔		-	-	↔	-	-	-	-	-
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25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	↔	-	→	-	-	-	-	↔	-	↔	-	-		-	-	-	-	-
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31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Table 11. Causality among gasoline price series (→ stands for information flows from row to column)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		-	↔	↔	↔	-	-	-	↔	-	-	-	-	↔	-	-	-	-	-	-	↔	-	↔	↔	-	-	↔	-	-	-	-
2	-		-	↔	-	↔	↔	-	-	↔	-	-	-	-	-	-	-	↔	-	-	-	↔	-	→	→	-	-	-	-	-	-
3	↔	-		↔	↔	-	-	↔	↔	↔	-	↔	-	↔	↔	↔	↔	↔	-	-	↔	-	↔	↔	-	-	↔	-	-	-	→
4	↔	↔	↔		-	-	-	-	↔	↔	-	↔	↔	↔	↔	-	-	↔	-	-	-	-	-	↔	-	-	-	-	-	-	-
5	↔	-	↔	-		↔	-	↔	↔	-	-	-	↔	↔	↔	↔	↔	↔	-	-	↔	-	↔	↔	-	-	↔	↔	-	↔	-
6	-	↔	-	-	↔		↔	-	↔	-	-	-	-	↔	↔	-	-	-	-	-	-	↔	↔	↔	→	-		↔	-	-	-
7	-	↔	-	-	-	↔		-	↔	↔	-	-	-	↔	-	↔	-	-	-	-	-	↔	↔	↔	→	-	-	-	-	-	-
8	→	-	↔	-	↔	-			↔	-	-	-	↔	-	-	↔	↔	↔	-	-	↔	-	-	-	-	-	-	-	-	-	-
9	↔	-	↔	↔	↔	↔	↔	↔		↔	-	↔	↔	↔	→	↔	↔	-	↔	-	↔	-		↔	-	-	↔	↔	-	↔	↔
10	-	↔	↔	↔	-	-	↔	-	→		↔	-	-	↔	↔	-	-	↔	↔	↔	-	-	-	↔	-	-	-	-	-	↔	-
11	-	-	-	-	-	-	-	-	-	↔		-	-	-	→	-	-	-	↔	↔	-	-	-	↔	-	-	-	-	-	-	-
12	-	-	↔	↔	-	-	-	-	↔	-	-		-	-	→	-	↔	↔	↔	-	-	-	-	-	-	-	↔	-	-	↔	-
13	-	-	-	↔	↔	-	-	↔	↔	-	-	-		-	-	-	↔	↔	-	-	-	-	-	-	-	-	-	-	-	↔	-
14	↔	-	↔	↔	↔	↔	↔	-	↔	↔	-	-	-		↔	↔	↔	↔	-	-	↔	-	↔	↔	-	-	↔	↔	-	↔	↔
15	-	-	↔	↔	↔	↔	-	-	↔	↔	-	-	-	↔		↔	↔	↔	↔	↔	↔	-	↔	-	-	-	↔	↔	-	↔	-
16	-	-	↔	-	↔	-	↔	↔	↔	-	-	-	-	↔	↔		-	↔	-	-	↔	-	-	-	-	-	↔	↔	-	↔	-
17	-	-	↔	-	↔	-	-	↔	↔	-	-	↔	↔	↔	↔	↔		↔	-	-	↔	-	↔	↔	-	-	→	↔	-	↔	-
18	→	↔	↔	↔	↔	-	-	↔	-	↔	-	↔	↔	↔	↔	↔	↔		↔	-	-	-	↔	↔	-	-	↔	↔	-	↔	↔
19	-	-	-	-	-	-	-	-	↔	↔	↔	↔	-	-	↔	-	-	↔		↔	-	-	-	-		-	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	↔	↔	-	-	-	↔	-	-	-	↔		-	-	-	-	-	-	-	-	-	-	-
21	↔	-	↔	-	↔	-	-	↔	↔	-	-	-	-	↔	↔	↔	↔	-	-	-		-	↔	↔	-	-	-	-	-	↔	↔
22	-	↔	-	-	-	↔	↔	-	-	-	-	-	-		→				-	-	-		↔	↔	-	-	-	-	-	-	-
23	↔	-	↔	-	↔	↔	↔	-	→	-	-	-	-	↔	↔		↔	↔	-	-	↔	↔		-	-	↔	↔	↔	-	↔	↔
24	↔	-	↔	↔	↔	↔	↔	-	↔	↔	↔	-	-	↔	-		↔	↔	-	-	↔	↔	-		-	→	→	-	-	→	→
25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	→	-	→	-	-	-	-	-	-		↔	-	-	↔	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	↔	↔	-		-	-	-	-	-
27	→	-	↔	-	↔	-	-	-	↔	-	-	↔	-	↔	↔	↔	-	↔	-	-	-	-	↔	→	-	-		-	-	-	↔
28	→	-	→	-	↔	↔	-	-	↔	-	-	-	-	↔	↔	↔	↔	↔	-	-	-	-	↔	→	-	-	→		-	↔	-
29	-	-	-	-	-	-	→	-	-	-	-	-	-	-	-	-	-	→	→	-	-	-	-	-	↔	-	-	-		-	-
30	→	-	→	-	↔	-	-	-	→	↔	-	↔	↔	↔	↔	↔	→	↔	-	-	↔	-	↔	→	-	-	→	↔	-		-
31	-	-	↔	-	-	-	-	-	→	-	-	-	-	↔	-	-	-	↔	-	-	↔	-	↔	→	-	-	↔		-	-	

Table 12. Causality among diesel price series (→ stands for information flows from row to column)

Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1		-	↔	↔	-	↔	↔	↔	↔	-	-	-	↔	-	-	↔	-	-	-	-	-	-	↔	↔	↔	-	-	-	↔	↔	-
2	-		-	-	-	-	↔	-	↔	↔	↔	-	↔	-	-	↔	-	↔	↔	-	-	↔	-	-	-	-	↔	-	-	-	-
3	↔	-		→	-	↔	↔	↔	-	-	-	-	↔	-	-	↔	-	-	-	-	-	↔	↔	↔	-	-	↔	↔	↔	↔	↔
4	↔	-	-		-	↔	↔	-	↔	↔	↔	↔	↔	↔	↔	↔	-	↔	↔		-	-	↔	↔	-	-	↔	↔	-	↔	-
5	↔	-	→	-		→	-	↔	-	-	-	-	↔	-	-	-	-	-	-	-	-	↔	→	↔	-	-	-	↔	↔	-	-
6	↔	-	↔	↔			↔	↔	↔	↔	↔	-	↔	↔	↔	↔	-	↔	-	-	-	↔	↔	↔	↔	-	↔	↔	↔	↔	-
7	↔	↔	↔	↔	-	↔		↔	↔	↔	-	-	↔	↔	↔	↔	↔	↔	-	-	-	-	↔	↔	-	-	↔	↔	-	-	-
8	↔	-	↔	-	↔	↔	↔		↔	-	-	↔	↔	↔	↔	↔	↔	↔	-	-	↔	↔	↔	↔	↔	→	↔	↔	↔	↔	↔
9	↔	↔	-	↔	-	↔	↔	↔		-	-	-	-	↔		↔	↔	↔	-	-	↔	↔	-	↔	-	-	↔	-	↔	↔	-
10	-	↔	-	↔	-	↔	↔	-	-		↔	-	-	↔	-	-	-	↔	↔	↔	-	↔	-	-	-	-	-	-	-	-	-
11	-	↔	-	↔	-	↔	-	-	-	↔		-	-	-	↔	-	-	-	↔	↔	-	↔	-	-	-	-	↔	-	-	-	-
12	-	-	-	↔	-	-	-	↔	-	-	-		-	↔	-	-	-	-	-	-	↔	↔	-	-	-	-	-	-	-	-	-
13	↔	↔	↔	↔	↔	↔	↔	↔	→	-	-	-		-	-	↔	↔	-	-	-	↔	↔	↔	↔	↔	↔	-	-	↔	↔	↔
14	-	-	-	↔	-	↔	↔	↔	↔	↔	-	↔	-		-	↔	↔	↔	↔	↔	↔	↔	-	↔		-	↔	-	↔	↔	↔
15	-	-	-	↔	-	↔	↔	↔		-	↔	-	-	-		-	↔	↔		-	-	-	↔	↔	-	-	↔	-	↔	↔	-
16	↔	↔	↔	↔		↔	↔	↔	↔	-	-	-	↔	↔	-		↔	↔	-	-	-	↔	-	↔	-	-	↔	↔	↔	↔	↔
17	→	-	→	→	-	→	↔	↔	↔	-	-	-	↔	↔	↔	↔		→	-	-	→	↔	-	↔	-	-	↔	↔	-	→	-
18	-	↔	-	↔	-	↔	↔	↔	↔	↔	-	-	-	↔	↔	↔	-		↔	↔	↔	-	↔	↔	-	-	↔	↔	↔	↔	-
19	-	↔	-	↔	-	-	-	-	-	↔	↔	-	-	↔	-	-	-	↔		↔	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-		-	-	-	-	-	↔	↔	-	-	↔	-	-	-	↔	↔		-	↔	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	↔	↔	-		↔	↔	↔	-	-	-	↔	-	-		↔	-	↔	-	-	-	-	-	-	-
22	→	↔	↔	→	↔	↔	→	↔	↔	↔	↔	↔	↔	↔	→	↔	↔	→	→	↔	↔		↔	→	↔	-	↔	↔	↔	↔	→
23	↔	-	↔	↔	-	↔	↔	↔	-	-	-	-	↔	-	↔	-	-	↔	-	-	-	↔		-	-	-	-	↔	↔	↔	-
24	↔	-	↔	↔	↔	↔	↔	↔	↔	-	-	-	↔	↔	↔	↔	↔	↔	-	-	↔	-	-		-	-	-	-	-	-	-
25	↔	-	-	-	-	↔	-	↔	-	-	-	-	↔	-	-	-	-	-	-	-	-	↔	-	-		-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-	-	↔	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-
27	-	↔	↔	↔	-	↔	↔	↔	↔	-	↔	-	-	↔	↔	↔	↔	↔	-	-	-	↔	-	-	-	-		↔	↔	↔	-
28	-	-	↔	↔	↔	↔	↔	↔	→	-	-	-	-	-	-	↔	↔	↔	-	-	-	↔	↔	-	-	→	↔		↔	↔	↔
29	↔	-	↔	-	↔	↔	-	↔	↔	-	-	-	↔	↔	↔	↔	-	↔	-	-	-	↔	↔	-	-	-	↔	↔		↔	-
30	↔	-	↔	↔	-	↔	-	↔	↔	-	-	-	↔	↔	↔	↔	-	↔	-	-	-	↔	↔	-	-	-	↔	↔	↔		-
31	-	-	↔	-	-	-	-	↔	-	-	-	-	↔	↔	-	↔	-	-	-	-	-	-	-	-	-	-	-	↔	-	-	

Appendix 1. Unit root tests for raw price series (level)

City	Code	Coal		Electricity		Gasoline		Diesel	
		t-stat.	Prob.*	t-stat.	Prob.*	t-stat.	Prob.*	t-stat.	Prob.*
Beijing	1	-0.71	0.841	-0.85	0.803	0.23	0.974	-0.64	0.859
Tianjin	2	-2.51	0.114	-0.38	0.909	0.30	0.978	-0.30	0.922
Shijiazhuang	3	-0.91	0.785	-1.55	0.506	0.43	0.984	-0.70	0.844
Taiyuan	4	-0.38	0.909	-0.19	0.937	-0.01	0.956	-0.50	0.889
Huhehaote	5	0.01	0.958	-2.15	0.224	0.19	0.972	-0.66	0.854
Shenyang	6	-1.15	0.697	-1.27	0.643	0.17	0.970	-0.82	0.812
Changchun	7	-0.47	0.894	-1.71	0.426	-0.20	0.935	-0.71	0.842
Harbin	8	-1.15	0.696	-1.79	0.387	0.23	0.974	-0.96	0.767
Shanghai	9	-0.99	0.757	-1.89	0.335	-0.03	0.955	-0.47	0.893
Nanjing	10	-2.28	0.180	-1.68	0.442	0.15	0.969	-0.57	0.873
Hangzhou	11	-0.70	0.845	-2.66	0.082	0.28	0.977	-0.35	0.914
Hefei	12	-0.23	0.932	-0.17	0.940	0.61	0.990	-0.11	0.946
Fuzhou	13	-2.63	0.088	-1.94	0.313	0.15	0.969	-0.73	0.835
Nanchang	14	-1.32	0.623	-1.97	0.300	0.10	0.966	-0.04	0.954
Jinan	15	-0.20	0.936	-1.83	0.364	0.09	0.965	-0.38	0.910
Zhengzhou	16	0.14	0.969	-1.98	0.295	0.19	0.972	-0.12	0.945
Wuhan	17	-0.01	0.956	-1.22	0.667	0.70	0.992	-0.22	0.933
Changsha	18	0.54	0.988	-1.72	0.420	0.13	0.968	-0.64	0.858
Guangzhou	19	-0.27	0.926	-1.96	0.305	0.21	0.973	-0.67	0.851
Nanning	20	-0.80	0.818	-1.23	0.664	0.29	0.977	-0.49	0.891
Haikou	21	-1.73	0.416	-1.75	0.407	0.23	0.974	-0.72	0.840
Chongqing	22	-1.60	0.482	-2.03	0.273	0.29	0.978	-0.10	0.947
Chengdu	23	-0.70	0.845	-1.49	0.538	-0.21	0.935	-0.27	0.927
Guiyang	24	-1.54	0.510	-2.40	0.142	-0.02	0.955	-0.53	0.881
Kunming	25	-0.56	0.877	-0.72	0.839	-3.85	0.083	-0.92	0.782
Lhasa	26	-	-	-1.89	0.335	-0.36	0.912	-1.28	0.640
Xian	27	-2.14	0.229	-2.98	0.088	0.21	0.973	-0.71	0.842
Lanzhou	28	-2.06	0.260	-2.28	0.180	0.61	0.990	-0.42	0.903
Xining	29	0.24	0.975	-0.58	0.872	-4.73	0.070	0.12	0.967
Yinchuan	30	0.53	0.988	-0.84	0.808	0.42	0.984	-0.62	0.863
Urumqi	31	-2.14	0.229	-2.21	0.202	0.38	0.982	-0.53	0.882

* MacKinnon (1996) one-sided p-values.
Note: Null hypothesis is that each series contains a unit root; ADF is the Augmented Dickey-Fuller test; Critical values: -3.44 (1% level), -2.87 (5% level) and -2.57(10% level).

Appendix 2. Unit root tests for coal and electricity raw price series (first difference)

City	Code	Coal		Electricity	
		t-stat.	Prob.*	t-stat.	Prob.*
Beijing	1	-4.93	0.000	-29.65	0.000
Tianjin	2	-19.77	0.000	-32.86	0.000
Shijiazhuang	3	-14.06	0.000	-9.83	0.000
Taiyuan	4	-22.06	0.000	-33.22	0.000
Huhehaote	5	-9.20	0.000	-30.45	0.000
Shenyang	6	-11.37	0.000	-11.13	0.000
Changchun	7	-4.52	0.000	-33.52	0.000
Harbin	8	-21.36	0.000	-27.74	0.000
Shanghai	9	-21.06	0.000	-31.29	0.000
Nanjing	10	-20.89	0.000	-29.63	0.000
Hangzhou	11	-5.70	0.000	-30.50	0.000
Hefei	12	-18.47	0.000	-33.14	0.000
Fuzhou	13	-10.03	0.000	-32.61	0.000
Nanchang	14	-23.39	0.000	-11.51	0.000
Jinan	15	-5.53	0.000	-27.18	0.000
Zhengzhou	16	-19.86	0.000	-6.98	0.000
Wuhan	17	-8.10	0.000	-28.84	0.000
Changsha	18	-12.11	0.000	-23.62	0.000
Guangzhou	19	-19.44	0.000	-29.34	0.000
Nanning	20	-20.47	0.000	-26.90	0.000
Haikou	21	-10.93	0.000	-32.77	0.000
Chongqing	22	-7.88	0.000	-10.91	0.000
Chengdu	23	-6.93	0.000	-32.20	0.000
Guiyang	24	-6.73	0.000	-28.91	0.000
Kunming	25	-14.13	0.000	-26.04	0.000
Lhasa	26	-	-	-11.28	0.000
Xian	27	-26.18	0.000	-34.10	0.000
Lanzhou	28	-6.66	0.000	-30.67	0.000
Xining	29	-19.20	0.000	-35.04	0.000
Yinchuan	30	-8.13	0.000	-21.56	0.000
Urumqi	31	-27.73	0.000	-31.08	0.000

* MacKinnon (1996) one-sided p-values.
Note: Null hypothesis is that each series contains a unit root; ADF is the Augmented Dickey-Fuller test; Critical values: -3.44 (1% level), -2.87 (5% level) and -2.57(10% level).